ECONOMIC AND ENVIRONMENTAL BENEFITS OF COPRODUCING POWER AND FUELS FROM DOMESTIC RESOURCES USING IGCC

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INTRODUCTION:

In compliance with the mission of Fossil Energy Power Systems to provide low cost, highly efficient power with minimal environmental impact from our nations fossil fuel resources, this paper describes a highly efficient and economically attractive configuration for the utilization of domestic coal and natural gas resources to coproduce electric power and high quality liquid transportation fuels in one integrated facility.

The Energy Information Administration (EIA) in its new 1998 International Energy Outlook[1] projects world energy use to grow by 70 percent between now and 2020 from 376 to 639 quads. Coal use is forecast to increase by 67 percent from 5,167 million short tons in 1996 to 8,627 million short tons by 2020. The majority of this increase being in the developing world, with China forecast to increase its coal use by a factor of 2.8. Oil use worldwide is forecast to increase by 62 percent from 72 to 116 million barrels per day, and natural gas use by over 100 percent from 82 trillion cubic feet (TCF) in 1996 to 172 TCF in 2020. Because of this large increase in world energy consumption and continued reliance on fossil fuels, carbon emissions are forecast to grow by 74 percent over this period.

Total energy consumption in the United States is forecast by the EIA[2] to rise by 26 percent between now and 2020. Oil use is projected to increase by 33 percent, natural gas by 46 percent, and coal by 28 percent. Most of the additional natural gas and all of the coal increase is forecast to be used for power generation. The resulting expected growth in carbon emissions as a result of this additional energy consumption is estimated to be 490 million tons or about 33 percent.

PROBLEM:

An analysis of both the world and the U.S. energy situations concludes that in the timeframe between the present and 2050, all of our fossil resources, including coal, will have to be used to satisfy continuing growth in energy demand. Concerns over the environmental impact of fossil energy use, particularly concerns over possible climate change as a result of carbon dioxide emissions continue to influence public policy and debate. Even without a potential global climate change threat, it is prudent and responsible to use our endowment of fossil resources in the most efficient and least polluting manner.

The challenge, then, is to determine how to use the combination of oil, gas ***and*** coal most efficiently with the minimum environmental damage. If coal, an inherently high carbon resource, must be used to provide energy, then it becomes an environmental imperative to develop and implement technologies that permit it to be used cleanly and efficiently.

APPROACH:

The overall approach should be to optimize a mix of resources and technologies to provide a mix of energy needs. It can easily be demonstrated, for example, that natural gas is superior to coal in most applications from a carbon emissions perspective. This has led some to the conclusion that natural gas use should be emphasized in *all* applications. This is an erroneous conclusion unless one assumes that there is enough gas to *satisfy* all applications. If this is not the case and it is necessary to use a combination of gas and coal, then we must use the gas in applications where its advantages are greatest, and use coal in applications where its advantages are greatest, and our R&D effort should be targeted to assure that coal is utilized in the most efficient and environmentally acceptable manner.

PROJECT DESCRIPTION:

To this end, the U.S. Department of Energy and Mitretek Systems have evolved and evaluated a concept that combines the use of gas and coal for the highly efficient production of electric power and high quality transportation fuels[3]. In its simplest form, (shown in Figure 1) this coproduction cofeed (CoCo) concept consists of diverting coal-derived synthesis gas from the combined cycle power block of an Integrated Coal Gasification Combined Cycle (IGCC) unit to a liquid Fischer-Tropsch (F-T) synthesis reactor. The unreacted synthesis gas from the F-T reactor, and imported natural gas are then combusted in the downstream combined cycle power generation unit. Combining processes in this manner accomplishes the equivalent of natural gas to liquid synthesis while eliminating the conversion losses associated with the production of synthesis gas from natural gas.

This concept of using both coal and natural gas to coproduce power and transportation fuels utilizes both feedstocks in an optimum manner. Coal cannot be combusted directly in gas turbines, it must first be converted into clean synthesis gas. Once in gaseous form, the high efficiencies associated with gas turbine performance now become accessible to coal. This is the rationale behind the IGCC concept. However, once the synthesis gas has been produced from the coal it is even more efficient to use this gas to produce liquid transportation fuels through F-T synthesis technology. Using a once-through F-T process, the inefficiencies of carbon dioxide removal and synthesis gas recycle can be avoided and the unconverted synthesis gas can be directly combusted in the gas turbines thereby benefiting from the high efficiency of gas turbine power production. This sequence of coal-derived synthesis gas utilization to produce fuels and power is thus optimized. For natural gas, optimum efficiency is realized by direct combustion in the gas turbines as in the concept described here.

RESULTS:

The development and deployment of clean coal technologies that allow coal to be used efficiently and cleanly to produce electric power in IGCC systems and to coproduce power and ultra-clean transportation fuels in one integrated configuration could be the harbinger of a new age of coal utilization. The CoCo concept represents the opportunity to make use of these new technologies to replace conventional coal utilization technology.

To quantify the carbon emissions advantages of this concept of cofeeding both coal and natural gas to an IGCC facility to produce both power and transportation fuels, it is necessary to compare this concept to the current way of producing electric power and liquid transportation fuels from conventional pulverized fuel (PC) combustion and petroleum.

Mitretek has developed detailed computerized system simulation models of these coal and natural gas conversion processes. These detailed models include the simulation of coal to power using pulverized coal combustion technology, the simulation of coal to power using advanced integrated gasification combined cycle (IGCC) technologies, the simulation of natural gas to power using natural gas combined cycle (NGCC) technology, and the simulation of coal and natural gas to produce a combination of power via combined cycle technology and high quality transportation fuels using Fischer-Tropsch (F-T) technologies.

BENEFITS:

Impact on Carbon Emissions:
Figure 2 shows an example of how the benefits of coproduction were quantified with respect to reduction of carbon emissions. In this case a conventional pulverized coal power plant is replaced by a CoCo facility. For the conventional coal power plant, 4,052 TPD of coal, equivalent to 2,877 TPD of carbon, produces 400 MW at an efficiency of 33 percent.   In the CoCo plant, a combination of coal and natural gas is used to produce the same amount of power (400 MW) and 6,083 barrels per day (BPD) of high quality F-T fuels. This combination of coal and natural gas required to produce this power and fuel is equal to 2,885 TPD of carbon, almost the same quantity of carbon needed to produce only the 400 MW of power in the PC case (2,877 TPD). Therefore, if one conventional coal-fired power plant is replaced by a CoCo plant, the 6,083 BPD of fuels are produced for **no additional increase in carbon.**

Nationwide, if all existing conventional coal-fired plants were to be repowered or replaced by CoCo facilities to produce the amount of electricity currently produced from coal (1,671 billion kWh of electricity), this would result in the use of 7 quads of natural gas and 14 quads of coal and the coproduction of 2.9 million barrels per day of high quality transportation fuels. Production of this fuel from domestic resources would save over 3 million BPD of imported crude oil with a resulting reduction in annual carbon emissions of over 150 million tons, almost a third of the EIA projected increase in carbon emissions in the U.S. between now and 2020.

If coal by itself were to be used to replace a PC plant and coproduce 400 MW of power and 6,083 BPD of liquid fuels instead of the combination of coal and natural gas, the schematic is shown in Figure 3. In this single feedstock coproduction case, 5,014 TPD of coal would be required (equivalent to 3,561 TPD of carbon) to produce fuels and power at an overall HHV efficiency of 52 percent. Approximately one third of the clean coal-derived synthesis gas bypasses the F-T unit and is sent directly to the gas turbines. The other two thirds of the synthesis gas is passed once-through the F-T reactors and the unconverted synthesis gas, the C_1 to C_4 hydrocarbons produced in the F-T synthesis, and the carbon dioxide are sent to the gas turbines. In this case if all existing PC plants were to be replaced by this coproduction system, 21 quads of coal would be required to produce the needed power and 2.9 MMBPD of fuels with a net reduction on carbon of 35 million tons per year.

Economic Considerations:
The capital cost of a grass-roots CoCo plant of the size described above is about $670 million. However, in many cases, it would be possible to reduce this by retrofitting or repowering existing coal-fired power plants rather than completely replacing them. The Wabash River CCT project is an example of this.

The required selling price for liquid fuels from a CoCo plant is highly dependent on the value of the coproduced power. In this analysis, it is assumed that the power must be sold at a price competitive with power from a natural gas combined cycle (NGCC) plant; that is, about 24 mills per kWh when gas is $2 per MMBtu rising to 37 mills per kWh when gas is $4 per MMBtu. Economic analysis of the CoCo plant estimates that, at a natural gas cost of $2.50 per MMBtu F-T fuels could be produced for about $29 per barrel of equivalent crude oil if the coproduced power is sold at 27 mills. This combination of sales would produce a return on equity (ROE) of about 15 percent for the plant owners. This means that to be competitive with an oil price of $20 per barrel an incentive worth $9 per barrel (or about 21 cents per gallon) would be needed to realize a 15 percent return on investment. Such a financial incentive could, for example, be provided by the government from revenues obtained from a carbon tax, or from exemption of state or federal fuel excise taxes. However, future prices for oil and natural gas are uncertain, and any increase in both has a substantial affect on the resulting cost of power and fuels produced from these facilities. For example, if future natural gas costs were $4 per MMBtu, then the liquid fuels produced by the CoCo plant would be sold at $22 per barrel to realize a 15 percent ROE. However, at that natural gas cost, a coal-only coprocessing plant could sell F-T liquids that are competitive with crude oil at $19 per barrel.

It is not only the price of oil and natural gas that influences the resulting costs of coproduced products. The capital cost of the technology has a significant impact. If continued R&D results in the deployment of advanced technologies that can reduce the cost of IGCC technology to be about $1,200 per kW, then the resulting cost of the coproducts can be reduced by about 25 percent.

FUTURE ACTIVITIES:

In future work the baseline CoCo facility described in this paper will be modified to include the improvements resulting from continued research and development activities both within government and in industry. These include improvements in coal gasification technologies, advances in F-T technologies, development of the Ionic Transport Membrane (ITM) system for synthesis gas production and air separation, and advances in power generation. The system efficiency improvements and cost reductions associated with the successful deployment of these improvements will be quantified in terms of the increased competitiveness of these advanced clean coal technologies.

CONTRACT INFORMATION:

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3) David Gray and Glen Tomlinson, *Efficient and Environmentally Sound Use of our Domestic Coal and Natural Gas Resources*, Energeia, published by University of Kentucky, Center for Applied Energy Research, Volume 8, No 4, Aug 1997.

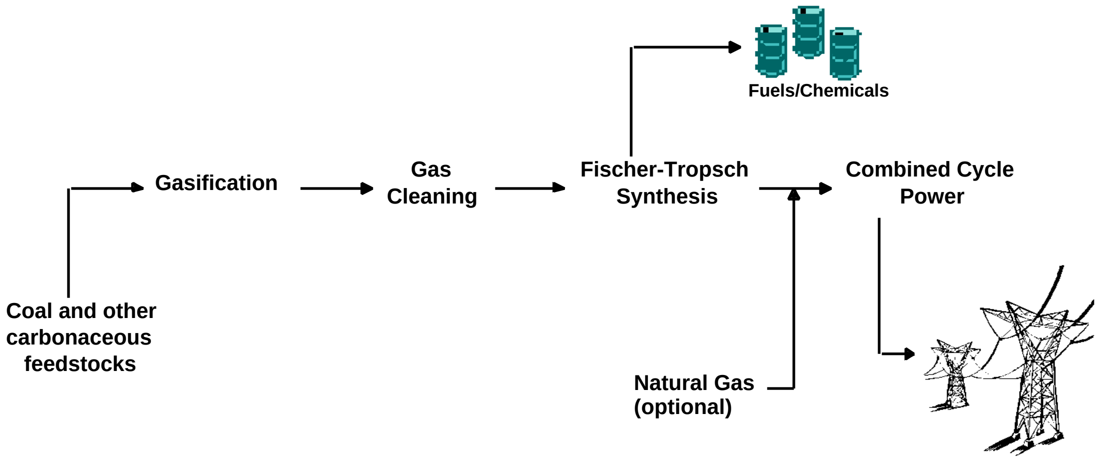

Figure 1: Coproduction Concept Schematic

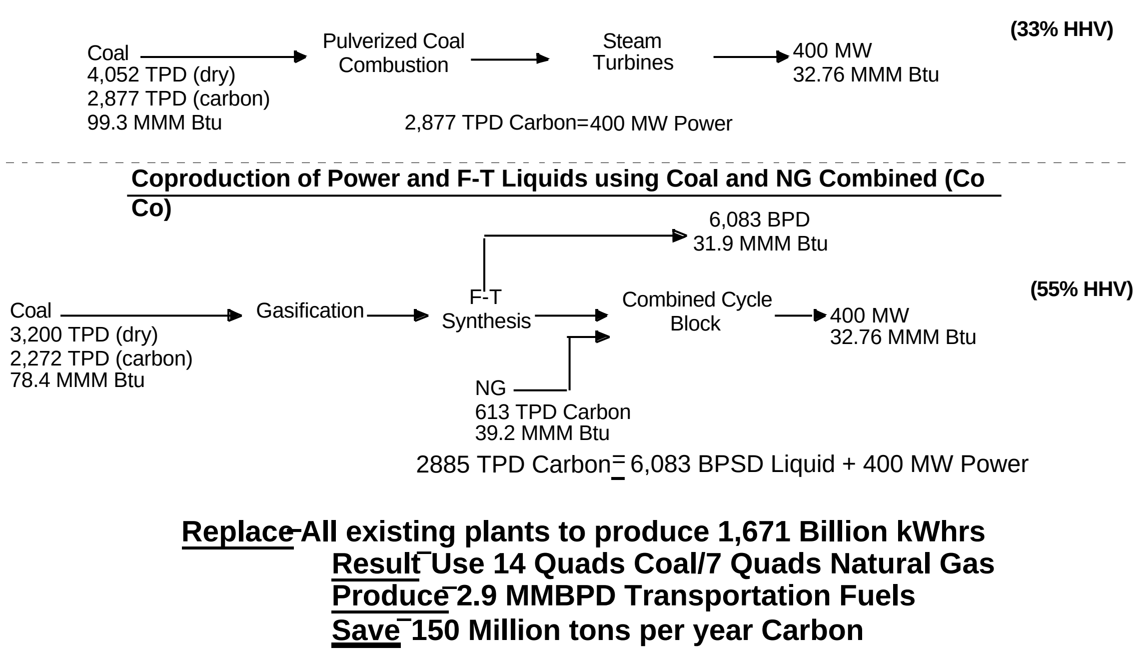

Figure 2: National Implications of Deploying CoCo Technology

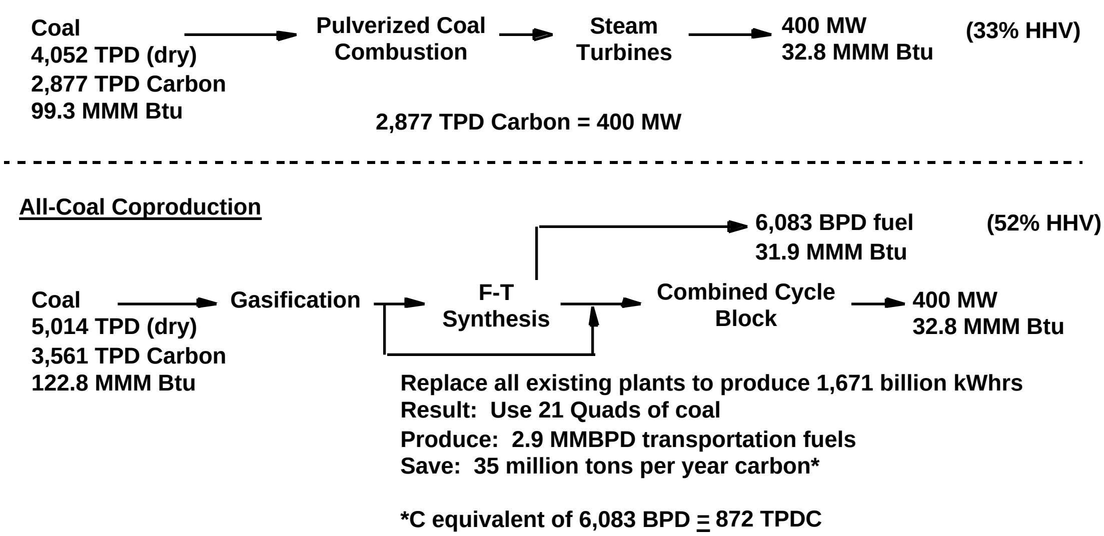

Figure 3: National Implications of Deploying Coal-Only Coproduction